

Influence of dipole fit time window on the quality of finger motor somatotopy

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1 Introduction

In the pioneering works [e.g. Foerster 1936, Penfield et al. 1937] hand motor somatotopy was described using electrical stimulation of the brain. Today, techniques like MEG, PET, or fMRI allow to show motor somatotopy noninvasively. While somatosensory mapping usually allows stable conditions, motor mapping is more difficult due to variabilities in movement execution. Therefore, there was a long debate about finger motor somatotopy organization which requires fine scale localization.

However, recent investigations in human subjects achieved with fMRI [Kleinschmidt et al. 1997, Lotze et al. 2000], MEG [Cheyne et al. 1991], and lesion studies [Schieber 1999] indicate that finger motor somatotopy exists, at least concerning the centers of mass of overlapping somatotopic regions. Our group recently described similar findings with MEG [Erdler et al. 1998, 1999].

The goal of the present study was to investigate the quality of dipole solutions for finger motor somatotopy depending on the time window for the dipole fit, and in addition to examine the influence of different filter settings on the localization results.

2 Methods

Nine experiments from a previous measurement series, showing the clearest somatotopic ordering, were analyzed. Subjects had to perform a brisk self-paced flexion of the 1st and 5th finger of the right hand every 3-4 s. 200 movements, arranged in blocks of 50 movements, had to be performed per finger. By using a home made splint and taping, movements were restricted to the metacarpophalangeal joint. Movement extent was standardized and restricted to about 1 cm.

Data recording was done with a digitization rate of 125 Hz and a low pass filter of 40 Hz. From the 143 available channels of a CTF whole head MEG system, 71 channels (mainly right frontal and parietal) were excluded to improve the signal to noise ratio. The data was filtered offline with a 2.9 Hz high pass to reduce SMA field components

and a 27 Hz low pass to cut off high frequencies. In addition, a window averaging filter - which replaced each time point by the average of itself and two time points before and two after it - was used as a low pass. Consequently, a time window of 5 time points (i.e. 32 ms) resulted, which was systematically moved over the maximum of the motor field (MF) to evaluate the separation of the two fingers depending on the time window location. For this, only the cranio-caudal axis was used, because in previous studies [see Erdler et al. 1998, 1999] it proved to be the most stable indicator.

Window averaging filters with filter length 1, 3, 7 and 9 time points were also applied to evaluate the effect of different window lengths.

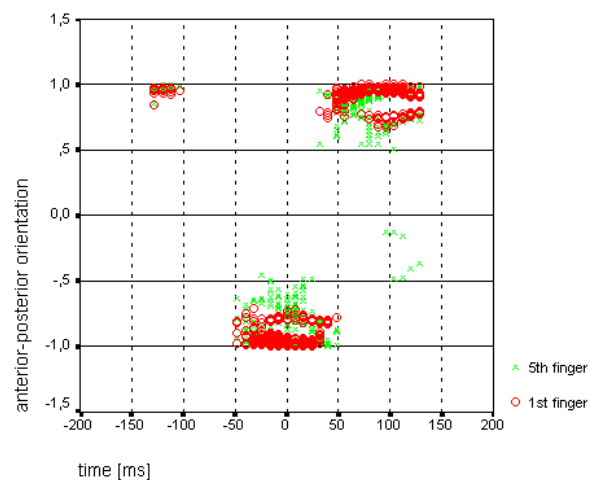


Figure 1: Scatterplot of norm vector anterior-posterior component of 1st and 5th finger motor dipoles using filter length 1, 3, 5, 7, and 9 superimposed into one diagram.

Only dipoles that explained at least 80% of the variance were accepted for data analysis. In addition a direction criterion was established. Since the motor dipoles are known to be located on the posterior lip of the precentral gyrus, they must be directed roughly anterior.

It can be seen in Fig. 1 that the norm vector anterior-posterior component of the motor dipoles reaches

almost -1.0 around the maximum of the MF at 0 ms and changes to $+1.0$ for the sensoric components of the motor evoked field I (MEFI) after the maximum of the MF. Therefore, only dipoles with a norm vector anterior-posterior component from -0.4 to -1.0 were used for further data analysis. This seems to be a rather loose criterion, but it clearly excludes most of the sensory components.

3 Results

In general, the dipole localization was quite stable before the MF maximum at 0 ms but showed less clear results immediately after it, which can be seen in Fig. 2 and 3. Note that with our analysis 0 ms corresponds to the maximum of the mean global field power of the MF, and *not* to the start of the EMG trigger.

In the range of -4 to $+2$ time points (i.e. -32 to $+16$ ms), the mean value of the time points (relative to the maximum) showing the best separation (i.e. highest distance) of the two fingers was -2.1 (i.e. -16.8 ms) before the maximum of the motor field when analysing the data with window length 5. At this time point, in contrast to the maximum of the MF (0 ms), the smallest distance between the two fingers as found with window length 5 is still clearly positive and the quadratic regression line has its maximum (compare Fig. 2).

These results could be approximately reproduced using other filter lengths (see Fig. 3). Fitting two time points before the maximum of the MF also led to good results if these other filters were used.

Interestingly, after the maximum of the MF it seems that the motor somatotopy inverts its order (see Fig. 2 and 3). Remember, that all the used dipoles explain at least 80% of the variance and point in a direction that would be expected from motor dipoles.

To evaluate the trend of the data linear and quadratic regression models were used. As can be seen from the R squared values (goodness-of-fit of the regression model) in Tab. 1 both linear and quadratic regression led to some significant results (depending on the used filter length). But the quadratic model clearly fits the data better than the linear one.

A look at Fig. 2 and 3 reveals that the maximum of the quadratic regression line is located almost exactly at -2 time points. Therefore, the regression analysis also suggests that 16 ms *before* the maximum of the MF is a good choice for the dipole fit.

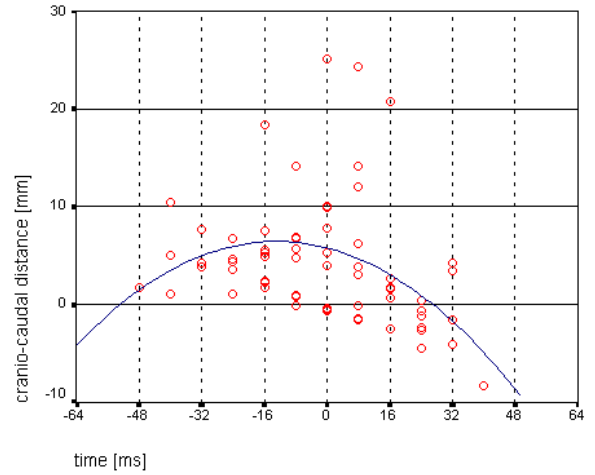


Figure 2: Scatterplot of cranio-caudal distance between 1st and 5th finger motor dipole depending on dipole fit time using filter length 5 with quadratic regression line.

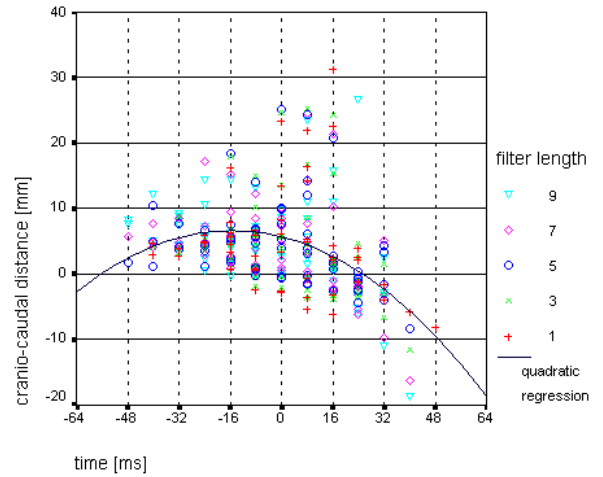


Figure 3: Scatterplot of cranio-caudal distance between 1st and 5th finger motor dipole depending on dipole fit time using filter length 1, 3, 5, 7, and 9 superimposed into one diagram with quadratic regression line.

Table 1: *R*-squared (goodness-of-fit) for linear and quadratic regression between cranio-caudal distance of 1st and 5th finger and dipole fit time depending on filter length. (* and ** mark significance at the 0.05 and 0.01 level.)

filter length	linear	quadratic
1	0.026	0.108
3	0.066	0.162**
5	0.068*	0.164**
7	0.172**	0.280**
9	0.167**	0.220**
All	0.091**	0.168**

4 Discussion

The quality of finger motor somatotopy results showed a clear dependency on the time window position, indicating that immediately before the maximum of the motor field the motor cortex generates high effector specific activity. Immediately afterwards, dipole solutions tend to produce an inverted somatotopy when typical motor dipole orientations are used. It is known that the activation of the primary motor cortex (M1) and the primary somatosensory cortex (S1) overlap to some extent in time [e.g. Gerloff et al. 1998], but our data suggests that sensory components may contribute to the motor field even at the maximum of the averaged MF (0 ms).

This is consistent with [Hoshiyama et al. 1997] who simulated the motor fields and found that the peak latency of a component is not necessarily consistent with that of the underlying source, because the waveforms must be considered to be a summation of different sources. For that reason, the time point of the maximum of a component may not be the best choice for dipole fitting in all cases.

Therefore, if one wants to reproduce finger motor somatotopy with MEG, it might be a good idea to fit the dipoles a few milliseconds (e.g. 16 ms) *before* the maximum of the MF when using the filter settings as described.

These data demonstrate the dependence of localization results on small time window shifts and may be of relevance for further fine scale somatotopic investigations.

Acknowledgements

This work was supported by the Austrian Science Foundation (P12451Med).

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